Update of the Measurement of the $t\bar{t}$ cross section at $\sqrt{s} = 1.96$ TeV

THE DØ COLLABORATION

Preliminary Result Presented at the Lepton Photon 2003 conference

Abstract

A measurement of the $t\bar{t}$ cross section at $\sqrt{s} = 1.96$ TeV is carried out on a data sample of ≈ 100 pb^{-1} in the dilepton and lepton+jets channels. Overall, 46 events are observed, with an expected background of 23.7 ± 3.0. The $t\bar{t}$ production cross section is measured to be:

$$\sigma_{p\bar{p} \to t\bar{t}} = 8.1^{+2.2}_{-2.0} \text{ (stat) } ^{+1.6}_{-1.3} \text{ (sys) } \pm 0.8 \text{ (lumi) pb.}$$

The preliminary measurement of the $t\bar{t}$ cross section at a center-of-mass energy of 1.96 TeV presented at the 2003 winter conferences [1] is updated with improved object identification algorithms and a larger data sample of approximately 100 pb^{-1}.

The analyses reported herein are based on data sets taken from August 2002, until July 2003, where ≈ 190 pb^{-1} were delivered to the experiment and ≈ 130 pb^{-1} were recorded and reconstructed. As the various analysis channels have different trigger criteria and quality requirements, the integrated luminosity corresponding to each channel varies (see Table 1). The trigger requirements are the same as those reported in [1]. The run data quality requirements that were applied in [1] are also applied to this larger dataset and are supplemented by additional data quality requirements based on smaller units of data called luminosity blocks (≈ 1 minute of data taking). These requirements reduce the effective data sample by 6%.

The most prominent change in the analyses occured in the identification of electrons, where a likelihood is now used to combine individual criteria, such as electromagnetic cluster χ^2 [1], spatial track matching, the E/p matching [1], the fraction of electromagnetic energy of the cluster [1], the distance of closest approach to the primary vertex (DCA) used to select primary high transverse momentum electrons originating from the primary interaction vertex, and the isolation with respect to nearby tracks. A reduction of a factor two in the background is obtained using a likelihood based selection. To further remove the heavy flavor multijet background in the analyses involving primary muons, a simple cut on the DCA is also applied.

Regarding specific improvements to the dilepton analyses, the $\ell\ell$ invariant mass windows (in which a higher missing transverse momentum was required to avoid the large $Z \to \ell^+\ell^-$ contribution), are now completely cut. In the $\mu\mu$ channel a cut on the azimuthal angle between the missing transverse energy and the leading muon, is applied to further reject events where

Table 1: Summary of the number of observed candidate events (N^{obs}), the number of signal events expected ($t\bar{t}$ Signal and background) assuming a $t\bar{t}$ cross section of 7 pb, the branching fraction ($\mathcal{B}$), the integrated luminosity ($\int \mathcal{L}dt$), the signal efficiency (ε) and the measured $t\bar{t}$ cross section (σ) for individual analysis channels.

Dilepton Channels						
	N^{obs}	Signal+Bkg.	$\mathcal{B}$	$\int \mathcal{L}dt$ (pb^{-1})	ε	σ (pb)
ee	2	1.2	0.012	107.0	7.0%	$15.8^{+19.8}_{-12.3}(stat)^{+6.2}_{-6.1}(sys)$
$\mu\mu$	0	1.2	0.012	90.4	6.0%	$< 7.7(stat)$
$e\mu$	3	2.3	0.025	97.7	10.5%	$9.7^{+8.4}_{-5.7}(stat)^{+2.1}_{-1.9}(sys)$
Lepton-plus-jets Channels (topological)						
	N^{obs}	Signal+Bkg.	$\mathcal{B}$	$\int \mathcal{L}dt$	ε	σ (pb)
e+jets	12	12.1	0.145	92.0	5.7%	$6.8^{+5.0}_{-4.1}(stat)^{+2.6}_{-2.5}(sys)$
μ+jets	14	18.5	0.145	94.0	7.2%	$2.3^{+4.2}_{-3.5}(stat)^{+2.9}_{-2.8}(sys)$
Lepton-plus-jets Channels (Soft Muon b Tag)						
	N^{obs}	Signal+Bkg.	$\mathcal{B}$	$\int \mathcal{L}dt$	ε	σ (pb)
e+jets	7	4.0	0.145	92.0	3.1%	$14.2^{+7.3}_{-5.6}(stat)^{+2.9}_{-2.1}(sys)$
μ+jets	8	6.5	0.145	94.0	4.5%	$9.5^{+5.2}_{-4.1}(stat)^{+2.1}_{-2.1}(sys)$

the missing transverse energy originates from the mismeasurement of one of the muons. A slight improvement in performance is obtained by requiring that both lepton tracks originate from the same primary interaction vertex.

Finally, the evaluation of the top contribution in the untagged W+jets sample in the soft-muon-tag analyses has changed. It now relies on the Berends' scaling hypothesis.

The summary of the results for all channels is given in Table 1. Altogether 46 candidate events are observed in the data in excellent agreement with the 45.9±3.5 events expected overall, assuming a $t\bar{t}$ production cross section of 7 pb. The total number of background events expected is 23.7±3.0. The significance of the excess, taking into account the systematic uncertainties on the number of expected background events, is 4.4 standard deviations. The probability for the observation to be compatible with the background only hypothesis is 1.1×10^{-5}.

The cross sections evaluated in each individual channel and the dilepton as well as the lepton+jets sub-combinations are illustrated in Figure 1.

Combining all individual channels, the measurement of the $t\bar{t}$ cross section yields:

$$\sigma_{p\bar{p}\to t\bar{t}} = 8.1 \ ^{+2.2}_{-2.0} \ (stat) \ ^{+1.6}_{-1.4} \ (syst) \ \pm 0.8 \ (lumi) \ \text{pb}.$$

This results is in good agreement with the present theoretical predictions using NNLO and NNNLL+ corrections [2, 3], as illustrated in Figure 2.

The leading source of systematic uncertainty on the combined measurement, 100% corelated among all channels, is the uncertainty on the evaluation of the luminosity, which amounts to a relative uncertainty of 10% on the cross section. The source of uncertainty with the next largest impact is the jet energy scale [1], with a relative uncertainty of 9.6%. The Soft-Muon-Tag lepton+jets analyses have the largest weight in this combination; the impact of the uncertainty on their background evaluation reflects into uncertainties on the combined cross section of 8.0% and 5.7% from the e+jets/μ and μ+jets/μ channels, respectively. The uncertainty on the jet energy resolution also implies a large uncertainty on the combined measurement (5.7%). A similar relative uncertainty results from the variation of the assumed top quark mass within its measured boundaries having an impact on the acceptoance estimation. Finally, the uncertainty on the evaluation of the W+multijet background in the topological approach, resulting from the Berends scaling hypothesis, amounts to $\approx$5.2% for each lepton+jets channel. All other sources have a significantly smaller impact on the combined result.

References

[1] The DØ Collaboration, "Measurement of the $t\bar{t}$ cross section at $\sqrt{s} = 1.96$ TeV", FERMI-Conf-03/200-E.

[2] M. Cacciari, S. Frixione, M. L. Mangano, P. Nason and G. Ridolfi, "The t anti-t cross-section at 1.8-TeV and 1.96-TeV: A study of the systematics due to parton densities and scale dependence," hep-ph/0303085.

[3] N. Kidonakis, "A unified approach to NNLO soft and virtual corrections in electroweak, Higgs, QCD, and SUSY processes," hep-ph/0303186.
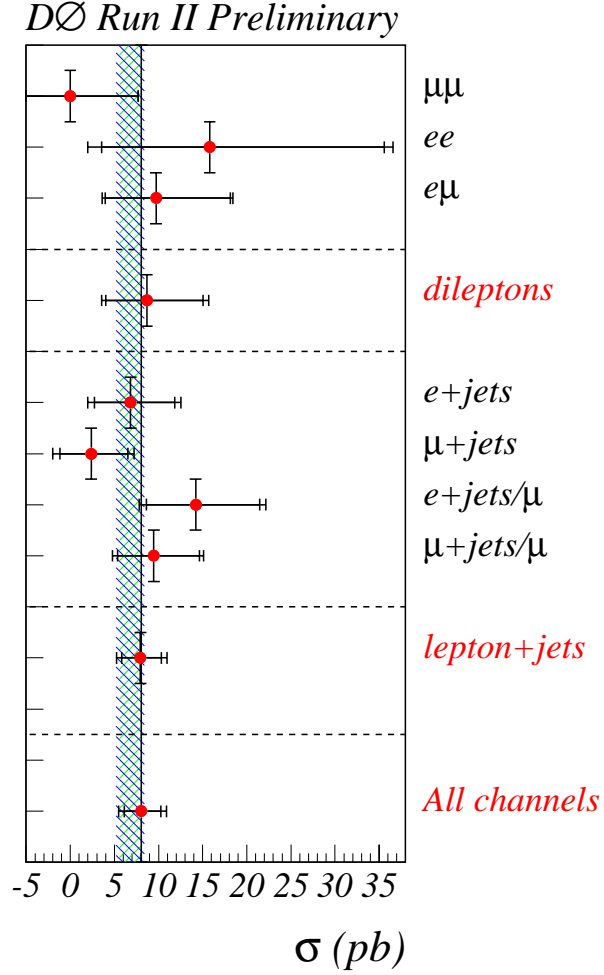
Figure 1: Summary of individual cross sections, dilepton and lepton+jets subcombinations, and the full combination of measurements. The theoretical prediction is indicated by the slanted band.
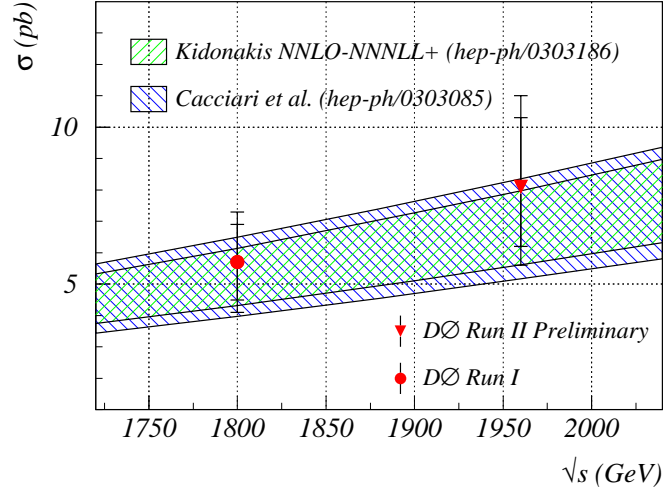
Figure 2: DØ measurements of the $t\bar{t}$ cross section at Run I and Run II and the $t\bar{t}$ cross section predictions as a function of the center-of-mass energy. The shaded regions reflect mostly the uncertainty on the measurement of the top mass, rather than the uncertainty on the theoretical prediction.